

Stream Overflow in Z Cha and OY Car during Quiescence

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ABSTRACT

Eclipses of the hot spot in Z Cha and OY Car observed by many authors during their quiescence are re-analyzed. Distances of the spot from the center of the disk r_s are determined from phases of ingress and egress. In the case of several eclipses of Z Cha and nearly all eclipses of OY Car it is found that $r_s(\text{egress}) < r_s(\text{ingress})$. This implies that they are not representative for the radius of the disk r_d and is interpreted as being due to the stream overflow. The $r_s(\text{ingress}) - dt$ relations (where dt is the time since last outburst) are improved when points affected by the stream overflow are omitted.

Key words: *binaries: cataclysmic variables, stars: dwarf novae, stars: individual: Z Cha, OY Car*

1. Introduction

Hot spot eclipses observed in dwarf novae provide an important tool for determining dimensions of their accretion disks and studying their evolution during the dwarf nova cycle (see Warner 2003, Smak 1996a and references therein).

In the standard approach it is assumed that the hot spot is produced by the collision of the stream with the outer parts of the disk. If so, the distance of the spot from the center of the disk r_s is identical with the radius of the disk r_d . In the case of such a "standard" hot spot the phases of mid-ingress ϕ_i and mid-egress ϕ_e are related to the mass ratio (defining the shape of the stream trajectory), the orbital inclination, the radius of the disk, and a certain parameter Δs describing the elongation of the spot along the disk's circumference (cf. Smak 1996a, 2007). Conversely, when q , i , and Δs are known, the phases of ingress and egress, ϕ_i and ϕ_e , can be used to obtain two independent values of the spot distance: $r_s(\text{ingress})$ and $r_s(\text{egress})$. It is obvious that they should be identical and this provides the crucial test for the applicability of the concept of a "standard" hot spot and – in particular – of the assumption that the radial distance of the spot is identical with the radius of the disk.

From the analysis of spot eclipses in U Gem (Smak 1971, 1996a) and IP Peg (Wolf et al, 1993, Wood et al. 1989b, Smak 1996a) it was found that the disk expands during normal outbursts and then slowly contracts during quiescence. This provides a strong observational support to the theory and models of dwarf nova outbursts (see Lasota 2001 and references therein).

In the case of Z Cha, however, it was found (O'Donoghue 1986, Zola 1989) that the radius of its disk also decreases during quiescence but the $r_d - dt$ diagram (where dt is the time since the last outburst) is more poorly defined, showing large scatter of points. (Somewhat surprisingly no such scatter is present in the $r_d - \phi_{cycle}$ diagram, where ϕ_{cycle} is the phase of the outburst cycle). In the case of OY Car the situation was even more disappointing: the $r_d - dt$ diagram (and also the $r_d - \phi_{cycle}$ diagram) shows large scatter of points with no clear dependence of radius on dt (cf. Smak 1996b).

The assumption of a "standard" hot spot breaks down when the stream overflows the disk and part of its kinetic energy is dissipated along its trajectory above and below the surface of the disk. The hot spot is then replaced with a "hot stripe", its "effective distance" from the center, as determined from the eclipse analysis, being no longer representative for the radius of the disk. Such a situation was identified recently among some of the eclipses observed in Z Cha and OY Car during their superoutbursts (Smak 2007, 2009). As a characteristic feature of such eclipses it was found that the spot distance $r_s(\text{egress})$ determined from egress is smaller than the spot distance $r_s(\text{ingress})$ determined from ingress. This was interpreted as being due to selfabsorption effects in the "hot stripe" when it is observed during ingress; due to those effects the distances obtained from ingress, $r_s(\text{ingress})$, come out much closer to the true radii of the disk.

The purpose of the present paper is to present similar evidence for Z Cha and OY Car at their quiescence, suggesting that their peculiarities discussed above can be explained as being due to the stream overflow.

2. Z Cha

Eclipses in Z Cha at quiescence were observed extensively by Cook (1985b), Cook and Warner (1984), O'Donoghue (1986) and Wood et al. (1986). Using the phases of ingress and egress, ϕ_i and ϕ_e , listed in those papers, with $q = 0.20$, $i = 80.2$ (Smak 2007) and $\Delta s = 0.02$ (Smak 1996a), we obtain the spot distances $r_s(\text{ingress})$ and $r_s(\text{egress})$, which are compared in Fig.1.

Most points do not deviate from the $r_s(\text{egress}) = r_s(\text{ingress})$ line by more than 10 percent and there are no points with $r_s(\text{egress}) > 1.1 \times r_s(\text{ingress})$. On the other hand, however, there are several points with $r_s(\text{egress}) < 0.9 \times r_s(\text{ingress})$, suggesting that they represent the case of stream overflow.

Supporting this interpretation is Fig.2, showing two $r_s - dt$ diagrams with values of r_s obtained from ingress and egress. As expected, the $r_s(\text{ingress}) - dt$ rela-

tion is quite well defined while the $r_s(\text{egress}) - dt$ relation shows large scatter due to effects of stream overflow.

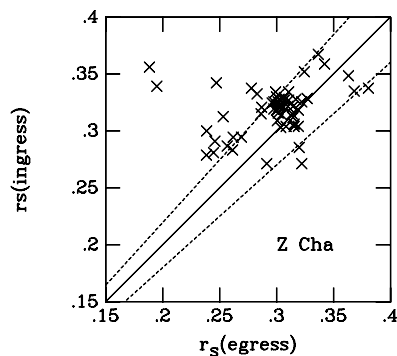


Fig. 1. Comparison of $r_s(\text{ingress})$ and $r_s(\text{egress})$ obtained for Z Cha at quiescence. Dotted lines represent $r_s(\text{egress}) = 0.9 \times r_s(\text{ingress})$ and $r_s(\text{egress}) = 1.1 \times r_s(\text{ingress})$.

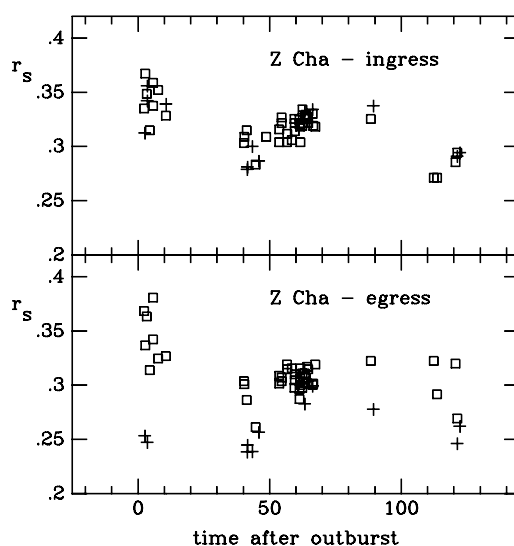


Fig. 2. Spot distances in Z Cha at quiescence – $r_s(\text{ingress})$ and $r_s(\text{egress})$ – are plotted versus time (in days) since the last outburst. Points with $r_s(\text{egress}) < 0.9 \times r_s(\text{ingress})$, indicating stream overflow, are plotted as crosses.

3. OY Car

OY Car and its eclipses were observed photometrically at quiescence by Beriman (1984), Cook (1985a), Schoembs (1986), Schoembs and Hartmann (1983), Schoembs et al. (1987), Vogt (1983), Vogt et al. (1981) and Wood et al. (1989a). Using the phases of ingress and egress, ϕ_i and ϕ_e , listed in their papers, with

$q = 0.10$, $i = 83.3$ (Wood et al. 1989a) and $\Delta s = 0.02$ (Smak 1996a), we obtain the spot distances $r_s(\text{ingress})$ and $r_s(\text{egress})$, which are compared in Fig.3.

Practically all points in this diagram show $r_s(\text{egress}) < r_s(\text{ingress})$, most of them deviating from the $r_s(\text{ingress}) = r_s(\text{egress})$ line by more than 10 percent. This suggests that we are dealing with effects of the stream overflow.

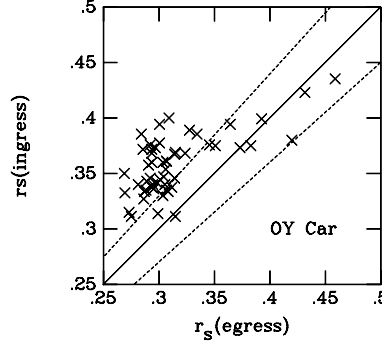


Fig. 3. Comparison of $r_s(\text{ingress})$ and $r_s(\text{egress})$ obtained for OY Car at quiescence. Dotted lines represent $r_s(\text{egress}) = 0.9 \times r_s(\text{ingress})$ and $r_s(\text{egress}) = 1.1 \times r_s(\text{ingress})$.

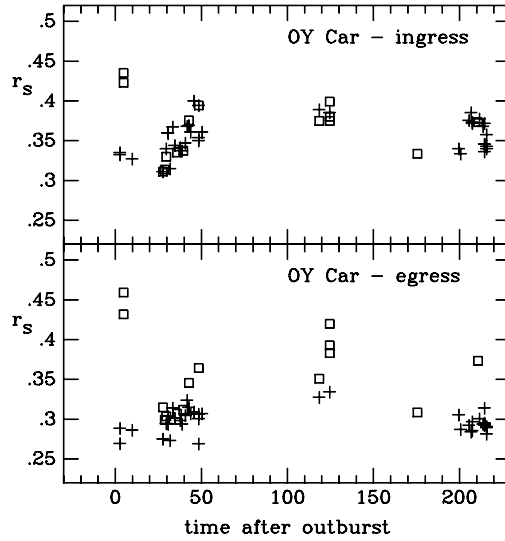


Fig. 4. Spot distances in OY Car at quiescence – $r_s(\text{ingress})$ and $r_s(\text{egress})$ – are plotted versus time (in days) since the last outburst. Points with $r_s(\text{egress}) < 0.9 \times r_s(\text{ingress})$, indicating stream overflow, are plotted as crosses.

Shown in Fig.4 are the two $r_s - dt$ diagrams with values of r_s obtained from ingress and egress. As expected, the $r_s(\text{ingress}) - dt$ relation is defined much better than the $r_s(\text{egress}) - dt$ relation. Note, however, that there are few squares (around $dt = 40$ d), which deviate *in minus* from the $r_s(\text{ingress}) - dt$ relation defined by

other points with $r_s(\text{ingress}) \approx r_s(\text{egress})$. This shows that – when the stream overflow is present – the equality $r_s(\text{ingress}) = r_s(\text{egress})$ does not always imply $r_d = r_s$.

4. Conclusion

It was predicted earlier by Hessman (1999) that stream overflow should occur most easily in quiescent dwarf novae, particularly those of the shortest orbital periods. Results for Z Cha and OY Car presented in this paper confirm those predictions. At the same time they form another important lesson, or warning: no reliable values of disk radii can be obtained from the analysis of eclipses of "hot stripes" produced by stream overflow.

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